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Review Article

A Review of Barriers and Benefits for Implementing Computational Thinking Initiatives in Secondary Schools

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Abstract

Computational thinking (CT) has become an essential skill for students to develop in preparation for an increasingly digital world. CT is widely recognized as a fundamental literacy important for student success across disciplines. However, significant barriers exist to integrating CT initiatives in secondary grades due to packed curricula, assessments, lack of teacher preparation, and the perception of CT as an isolated skill. This narrative review aims to analyze secondary schools' major obstacles and the significant advantages they can attain in instituting computational thinking programs. A narrative analysis of recent literature synthesizes the two key themes, namely the barriers and benefits related to secondary CT integration to elucidate the necessary trade-offs, priorities, and costs to provide well-informed, equitable recommendations for implementing solutions. In summary, while the integration of CT in secondary schools is imperative for equipping students with future-ready skills, it requires addressing teacher misconceptions and structural barriers. Properly prioritized, CT literacy has the potential to revolutionize secondary education pedagogy and empower students to become proactive creators of technology.

Keywords: Computational thinking, narrative review, secondary education, barriers, benefits.

INTRODUCTION

As technology continues to evolve and amalgamate itself into every industry and daily life activity, computational thinking has become an essential skill set for students to master. However, implementing it effectively requires overcoming some challenges. On the one hand, according to Srinivasa et al. (2022), computational thinking involves breaking down complex problems into manageable chunks, analyzing data patterns, developing step-by-step solutions algorithms, and using technology to automate solutions and processes. These skills empower students to shift from simply using technologies to understanding the logical foundations of how computer systems operate, so they can leverage technology more effectively and creatively.

Nonetheless, integrating computational thinking across subjects poses difficulties. One challenge is that many teachers lack specialized computer science training given overloaded credentialing centered on traditional literacies. Additionally, with minimum exposure to programming or cross-disciplinary technology applications, they may struggle to model computational techniques in lessons and activities (Tsortanidou et al., 2023).

Stipulating professional development to assist educators in learning these skills is necessary. Conversely, this approach risks superficial additions without addressing pervasive human capital barriers. Eventually, scaffolded professional development communities personalized to teacher backgrounds should mitigate the challenges posed by unfamiliarity, which inhibits the authentic diffusion of computational literacy.

In advance, programming was considered a specialized skill set limited to technicians, but it has evolved into a globally recognized trend being integrated into curriculum development cycles. This transformation indicates shifting perspectives on the value of programming abilities in modern education. The paradigm shift is evidenced by proactive measures taken by education policymakers in various countries during the 2000s.

In reaction to demands for 21st-century skills, these policymakers initiated the inclusion of computer science in school curricula, reflecting a commitment to preparing students for the digital age by highlighting the cultivation of these skills from a primary level.

This approach focuses on fostering programming-related competencies among primary school students, introducing fundamental concepts of coding, problem-solving, and logical thinking (Dagienė et al., 2022). The goal is to provide students with a foundational understanding of computational thinking and an array of widely applicable analytical and problem-solving abilities grounded in computer science. This proactive educational strategy intends to equip students for the evolving landscape of the digital era by developing their proficiency in areas essential for success in the 21st century (Hasbullah et al, 2022).

Furthermore, introducing computational thinking across secondary school curriculums provides potential opportunities to address representation gaps in high-tech fields; however, equitable implementation remains a challenge. Expanding early exposure and applied training to underserved populations can help mitigate systemic biases and background knowledge deficits that later deter marginalized groups from entering technology careers (Davis-Hall et al., 2023).

Nonetheless, schools should align these initiatives with additional guidance, resources, and community partnerships specifically tailored to support students from disadvantaged backgrounds (Bryan et al., 2020; Sudin et al., 2022). While capturing widespread early interest in computational thinking is a crucial first step for strengthening diverse talent pipelines, fostering ongoing participation and career pursuit requires a nuanced, multipronged strategy accounting for continuing barriers.

Malaysia's integration of computational thinking across secondary school curricula demonstrates governmental commitment to addressing educational gaps in technological competencies critically needed to navigate increasingly digitized life, learning, and work (Ramli et al., 2023). Particularly, this reform-oriented prioritization of computational literacy signifies acknowledging policy insufficiencies that permitted students to lag global peers in technological fluency and participatory readiness.

However, favorable initiatives must transition from fragmented pilots needing more coordinated support into systemwide pedagogical transformation backed by long-term resource allocation and continual optimization.

Additionally, through the Second National Science Policy advancing science and technology as instrumental to socioeconomic development, Malaysia has recognized the escalating need for homegrown talent to power digital transformation (Mansor, 2022). Furthermore, this necessitates constructing participatory learning ecosystems connecting schools, families, industries, and civil society to cultivate computational perspectives collectively.

Moreover, attuning curriculum to leverage students' existing digital engagement forges intrinsic connections, cementing persistent computational competencies adaptable to unpredictable futures (Ghafar et al., 2023). Finally, upholding this undertaking requires policy coherence, talent development, and cultural perception shifts to convert rhetoric into the designated reality of computational citizens.

Policymakers worldwide have recognized the importance of cultivating programming-related competencies from a primary level, preparing students for the digital age and equipping them with essential skills for success in the 21st century (Roslin et al., 2022). Additionally, integrating computational thinking into secondary school curricula presents opportunities to address representation gaps in high-tech fields and foster diverse talent pipelines.

However, equitable implementation remains a challenge, necessitating additional support, resources, and partnerships tailored to students from disadvantaged backgrounds (Ahmad Shahrizal et al., 2022). Overall, it is of utmost importance to nurture computational perspectives in students to empower them as active participants in a digitized world, while also acknowledging the systemic barriers that need to be addressed for the successful integration of computational thinking initiatives in education.

In summary, integrating computational thinking across disciplines furnishes secondary students with transferable skills that unlock their potential for personal and professional success while identifying pragmatic challenges schools confront in implementation. It transitions students from passive consumers to active shapers and creators of technology, opening abundant opportunities for their academic and career pursuits in the 21st-century landscape. Initiating this literacy and capability-building early on enables all students to thrive in an increasingly digitized world.

METHODS

For this research utilizing a narrative review approach. The approach uses synthesized relevant literature to provide an overview of key developments, debates, and insights on barriers and benefits surrounding secondary school implementation of computational thinking initiatives. Searches queried two academic databases - SCOPUS and ERIC using combinations of keywords like "computational thinking," "computer science education," "secondary school," "barrier," "challenges," "obstacles," "benefit," and "advantages". Initial scoping identified over 100 potentially relevant articles.

Following this, the researchers discussed various inclusion and exclusion criteria they had carefully developed. One of the primary criteria used was the consideration of literature, specifically research articles, as the main source of practical information. Consequently, any publications in the form of systematic reviews, reviews, meta-analyses, meta-syntheses, book series, books, chapters, and conference proceedings were included in the current study.

Furthermore, the review focused exclusively on papers written in English, a widely accepted language in the academic community. Inclusion criteria focused the review on empirical studies from 2021 until 2024, discussing the situating of CT integration specifically within secondary school contexts.

FINDINGS

This study uncovers two key themes surrounding the implementation of computational thinking initiatives in secondary schools, namely the barriers that hinder progress and the advantages that make the accomplishments worthwhile. In the following sections, the discussion dives deep into the two major themes.

Barriers to Implementing CT Initiatives in Secondary Schools

These discussions conceive implementing computational thinking across secondary curricula faces several key barriers. In addition, a major barrier preventing the widespread implementation of computational thinking skills in secondary schools is the institutional focus on standardized testing in conventional subjects like mathematics, reading, and writing (Altın, 2021). Likewise, Feng and Yang (2022), have also identified implementing CT initiatives in secondary schools as the competing priorities placed on core subjects like reading and mathematics.

With the emphasis on standardized testing and the pressure to meet academic benchmarks in these areas, teachers often find it challenging to allocate sufficient time and resources to encompass CT-related activities. As a result, most instructional time, and professional training quintessence on the tested subjects instead of developing emerging technical abilities comparable to computer science concepts, programming, data analysis, and complex problem solving (Sun et al., 2023).

Realistically, teachers may distinguish growing importance but feel pressured to meet existing targets (Kilag et al., 2023). While foundational literacy and numeracy skills remain essential, exclusively prioritizing them risks positioning digital competencies as merely supplemental rather than increasingly vital in a technology-driven economy (Smith, 2023).

On the other hand, advocates for integrating CT across all subjects contend that this approach enables students to recognize the versatility and applicability of computational thinking in various contexts. By embedding CT principles within existing subjects such as mathematics, science, and language, teachers can demonstrate the relevance of these skills in solving real-world problems and foster interdisciplinary connections.

However, implementing this cross-curricular approach requires a significant overhaul of the existing curriculum, extensive teacher training, and a shift in educational priorities. Next, a predominant obstacle hindering computational thinking diffusion into secondary curricula stems from scarce technological infrastructure and hardware access, especially acute in lower-income districts (Williams, 2022).

In another study, Hasin & Nasir (2021), conducted a survey showing that rural education faces issues with technology facilities. Specifically, some schools do not have adequate technology infrastructure and support materials to assist the teaching and learning process, especially computers and computer laboratory facilities.

Consequently, the lack of ICT materials makes teachers less skilled in the use of ICT. In line with this, the implementation of computational thinking (CT) in learning will also be disrupted as a result. Unfortunately, acquiring extensive technology tools to furnish participatory constructionist pedagogies for entire classrooms requires substantial funding often unavailable with competing budget priorities and assessment pressures (Ung et al., 2022).

While some schools successfully provide 1:1 device allotment through specialized grants or community partnerships, creative solutions like rotating computer lab schedules or sharing displays can circumvent short-term gaps (Meza, 2023).

Vinnervik (2022) suggested that even trained, enthusiastic teachers cannot implement CT effectively without sufficient technological infrastructure, hardware access, and technical troubleshooting assistance. Thus, funding limitations consistently impose resource scarcity, particularly in schools serving lower-income communities (Williams, 2022). Creative partnerships with industry donors along with governmental investments offer paths to equitably bridging these digital divides.

However, absent system-wide commitments to closing the secondary CT resource gap, pioneering adopters tend to come from typically privileged schools unrepresentative of wider capacities and constraints (Brizard, 2023).

Furthermore, educators who are enthusiastic about CT adoption also face steep learning curves given limited familiarity with coding languages, lesson planning, and making meaningful cross-disciplinary connections (Law, 2023). Specifically, while eager to prepare students with versatile digital skills, most secondary educators pursued humanities-focused credentials absent modern coursework in programming, data analytics, or cross-disciplinary technological applications (Yadav et al., 2021).

Additionally, with overloaded training centered on conventional literacies, teachers lack fluency in conveying algorithmic abstraction, conditional logic, automation basics, or other pillars underpinning computational analysis across subjects (Bocconi et al., 2016). Even intrinsically motivated instructors can thus struggle to transition from traditional pedagogies towards immersive, project-based computational activities without solid mentoring scaffolds (Meerbaum-Salant et al., 2022). Without comprehensive onboarding and ongoing professional development provided, the capacity to implement CT broadly remains restricted to just a few isolated teaching innovators rather than being adopted at a systemic level.

However, researchers equally recognize pervasive knowledge gaps among in-service educators around foundational principles like abstraction, algorithmic logic, data interpretation, and design thinking underlying computational analysis across subjects (Othman et al., 2023). Our results support tailored professional development for non-computing teachers to develop a contextual understanding of computational concepts and frame working connections to existing goals beyond isolated skills training (Mouza et al., 2022).

Effective diffusion relies on elevating broader pedagogical fluency in managing project-based learning and cooperative knowledge construction suited to immersive computational activities (Boulden, 2020). With coordinated support scaffolding humanities-oriented teachers through mentorship and formal credential pathways, school systems can progressively transition industrial-era academics into environments preparing students to judiciously shape technological futures.

Additionally, cultural barriers with negative stereotypes portraying computer science as asocial, competitive, and aligned with male dispositions further constrain secondary CT integration (Hsu et al., 2022). Countering these biases through diverse role models and framing CT as an inclusive creative endeavor enhances engagement for underrepresented groups like young women who often self-select out of elective CS courses (Aliabadi, 2023).

However, such culture shifts require patiently enacting representational best practices within individual classrooms until perceptions modernize across broader communities and media discourses. While substantial barriers exist, the considerable educational benefits should compel secondary schools to tackle obstacles facing computational thinking (CT) integration.

Specifically, teaching CT and computer science concepts from an early age promotes vital abilities like critical thinking, creativity, problem-solving, and logical reasoning that transfer flexibly across academic domains and life complexities (Falloon, 2024). Starting in adolescence scaffolds CT skills upon the analytical developments emerging during secondary education more effectively than introducing such competencies strictly in adulthood after modes of thinking solidify (Falloon, 2024).

Benefits from Implementation of CT Initiatives in Secondary Schools

Integrating computational thinking across secondary curriculums holds immense potential for cultivating vital future-ready competencies like critical analysis, creative ideation, and adaptive problem-solving. Grounding activities in real-world interdisciplinary contexts frames coding as a fundamental tool for investigation and impact rather than an isolated technical field (Tawfik et al., 2024). Thus, reframing programming as a creative capacity for understanding and solving complex systems also provides students in shaping the technologies affecting society.

When computational literacy is formulated as a pathway for equitable participation, secondary schools can subsequently equip students with transferable abilities to ethically navigate increasing technologization. In addition, it enables students to progress from passive technology consumers to active creators capable of inventing their solutions.

Likewise, programming shifts from an opaque specialty skill to a personally empowering tool for making positive community change through apps addressing local issues. Furthermore, devices transform from closed black boxes to flexible platforms for designing artistic projects reflecting students' distinctive perspectives.

Therefore, allowing young generations to shape technologies for themselves subsequently builds agency and buy-in. As a result, students focused on real-world creativity and problem-solving also promote computational literacy and valuable efficiencies across domains.

Likewise, inventing an intuitive understanding of essential concepts like automation, algorithms, and data organization also assists students in effectively utilizing existing tools. Furthermore, while specialized coding languages frequently focus on functional syntax, emphasizing underlying logic patterns, abstraction processes, and modularization techniques also helps graduates transfer knowledge across programming platforms (Alam, 2022).

Centering programming education on tangible interdisciplinary problems and modeling solutions on recognizable phenomena also assists learners in connecting computational concepts to daily life, such as creating basic physics simulations echoing playground experiences and grounds otherwise nebulous terms in concrete application. Having students invent phone apps addressing environmental issues shows direct high school relevance. Framing coding around relatable contexts improves meaning-making, retention, and attitudes.

Additionally, enabling students to create personally relevant applications also fosters greater engagement and enjoyment with material otherwise considered abstract or intimidating. Furthermore, student-driven creative projects tapping into intrinsic motivations subsequently promote the active construction of understanding (Hanafi et al., 2023). Moreover, pairing and group activities also reinforce participatory learning through peer exchanges.

Finally, facilitating personalized, socially interactive experiences consequently appeals to learner attitudes and backgrounds critical for broadening access. Likewise, starting computational thinking skill-building early at the secondary level allows students to accumulate expertise progressively alongside emotional readiness and evolving perspectives (Kucuk & Sisman, 2020).

Furthermore, longitudinal integration of computational perspectives across core subjects also enables scaled scaffolding of skills and mindsets towards careers leveraging technology for discovery and innovation. Finally, sustained, equitable exposure granting early agency and voice builds familiarity and affection while countering stereotypes about who can experience our digital future.

DISCUSSION

Recommendations to Overcome Barriers to Implementing CT Initiatives in Secondary Schools

As highlighted, the themes of barriers and benefits of computational thinking initiatives in education emerge prominently. On one hand, integrating computational thinking skills into students' education is seen as essential in an increasingly technology-driven world. Students can understand and leverage technology more effectively by mastering computational thinking and transitioning from technology users to creators. However, several challenges restrict the effective implementation of computational thinking initiatives.

One major barrier is teachers' need for specialized computer science training, leading to difficulties in modeling computational techniques in lessons. In addition, the urgency for professional development is tailored to educators' backgrounds to address the gaps in expertise and facilitate the authentic diffusion of computational literacy.

Computational literacy and efficiency will continue growing in importance in future decades across white-collar and blue-collar careers as automation and artificial intelligence permeate industries.(Bashynska & Zaichenko, 2023). Providing foundational exposure to algorithms, data structures, abstraction, and automation readies students to harness rather than simply be passive consumers of pervasive technologies (Hanafi et al., 2023). As students actively ideate solutions using programming languages, they transition from users to creators equipped for advanced innovation economies centered on public welfare through technological or policy contributions (Simeon et al., 2020).

However, this relies on constructing participatory learning ecosystems connecting schools, families, industries, and civil society to cultivate adaptable computational perspectives across subjects collectively (Hurley et al., 2021). In addition, computational integration should empower socioemotional growth and ethical citizenship, surpassing workforce skill provision.

Furthermore, framing computer science as a creative endeavor connected to student interests increases engagement through active, hands-on pedagogies much more so than passive tutorials (Lee et al., 2023). Realizing the fullest potential of secondary computational thinking integration relies on grounding projects in contexts connecting to students' existing curiosities and cultures rather than imposing abstracted programming tasks (Bocconi et al., 2022).

Allowing students to explore communal challenges from localized lenses leverages adolescent drives toward conceptualizing creative solutions with authentic relevance. Designing technologies that students recognize as upholding family or cultural values reinforces computational modes as concrete tools for modeling real-world systems, not just theoretical exercises (Lee et al., 2023).

Nevertheless, several key strategies can set the stage for success despite implementation hurdles. Namely, offering teachers more ongoing professional development should build computational fluency. Additionally, starting with small pilot programs allows for controlled testing and refinement before broader rollouts. Providing the required technical resources and infrastructure lays the groundwork for wider integration. Gaining administration and community support through awareness campaigns should also smooth adoption. Moreover, pairing newcomers with experienced peers enables collaborative skill-building along the way.

Eventually, integrating computational concepts creatively into core subjects makes adoption organic and sustainable. While progress may require persistence through expected growing pains, schools ultimately owe it to students to provide this 21st-century preparation that pays dividends across disciplines and life.

Realizing the considerable benefits of secondary computational thinking (CT) integration requires transitioning from superficial exposure to immersive multidimensional transformation (Kwon et al., 2022). Rather than the one-way transmission of coding skills detached from relevance, student-centered, real-world connected approaches more effectively build sustainable computational literacies (Jeon, 2023). This entails scaffolding iterative skill application through project-based learning where students map solutions to community problems using technology (Nadir, 2021).

Constructivist pedagogies enable this more mysterious, participatory embedding of computational perspectives across subjects and everyday contexts beyond narrow software training (Shamir & Levin, 2022). Moreover, through guided exploration and collaborative discourse, students engage with overarching computational concepts such as abstraction, algorithms, automation, design thinking, and data interpretation. The educator's role is to scaffold these learning experiences, providing structure and support while allowing students the autonomy to navigate their path of inquiry (Mouza et al., 2022).

In addition, the students then document and present how computational frameworks analyze learning topics from literature to mathematics to science while wrestling with big questions like algorithmic accountability and prizes versus perils of artificial intelligence (Dwyer et al., 2020). Rather than rigid curricular marching through abstract coding syntax to be memorially regurgitated on traditional tests, project-based learning grounded in real-world connections suits secondary cognitive advancements (Relstab, 2023).

Explicitly, student-centric pedagogies like collaborative design projects, creative computational artifact construction, and cross-disciplinary problem-based tasks can demystify coding misperceptions through participatory, socially situated knowledge-building (Wintrode, 2020). Furthermore, this scaffolding through the cooperative creation of shared artifacts makes abstract concepts like variables, conditionals, and functions more accessible by connecting directly to tangible goals students set (Smith et al., 2023).

Nevertheless, the programming frequently stimulates student frustrations through cryptic bugs, design obstacles, and interpersonal conflicts on collaborative teams (Lin et al., 2023). Rather than intervening prematurely, providing scaffolded space for students to confront impediments facilitates gritty persistence essential for computational mastery. Specifically, navigating buggy code and suboptimal prototypes incubates debugging determination, growth mindsets, and critical thinking exceeding smooth sailor projects (Hanafi et al., 2023).

Additionally, educators must sparingly mentor meta-cognitive strategies like explaining errors, tracing causations, controlled testing, divide-and-conquer plans, and team communication without erasing productive struggle essential for resourcefulness (Vieira et al., 2021). Programming barriers mirror real-world complexities. Learning to incrementally decode illogical machine feedback and candidly discuss directions for improvement prepares students to meet unforeseeable challenges in future education, careers, and civic participation (Walther, 2021).

Rather than being inherently frustration-free, engaging in programming equips students with the coping capacity to convert uncertainties and challenges into creative problem-solving opportunities through a process of reasoned unraveling.

Constructive friction experienced during the learning journey helps to forge computational resilience - a valuable skill that extends well beyond school tasks and into real-world scenarios. By grappling with complex issues, debugging errors, and persevering through obstacles, students cultivate the mental flexibility and tenacity needed to thrive in an increasingly digital landscape.

Enacting these student-centered learning environments relies on comprehensively onboarding teachers into guiding rather than dictating participatory journeys (Martin-Lindsey, 2021). This pedagogical shift requires scaffolding of both computational and facilitative competencies. Ongoing communities of practice meld top-down templates with bottom-up customization attuned to localized strengths and needs.

Secondary schools must also engage families and community partners in collectively applying CT to civic issues, showcasing diverse applications (Yu et al., 2020). Equitably implementing immersive technology education requires embracing student voices and co-designing initiatives responsive to marginalized communities' interests rather than obscuring diverse viewpoints (George, 2023). As secondary school represents a pivotal transition from consuming to creating technologies, Computational Thinking skills can prepare students as creative leaders spearheading Malaysia's digital transformation according to balanced local values (Anuar et al., 2020).

However, this relies on constructing national talent pipelines through participatory pedagogies grounded in global representativeness, ethical accountability, and innovation accessibility. Teacher readiness thereby represents a pivotal prerequisite for scaling equitable access (Davis, 2023).

Current Practice of CT in the Secondary School Curriculum in Malaysia

In recent years, Malaysia has recognized the importance of integrating computational thinking (CT) into its secondary school curriculum to prepare students for the demands of the 21st century. The Ministry of Education has taken steps to incorporate CT concepts and practices into various subjects, with a focus on Science, Technology, Engineering, and Mathematics (STEM) education. One notable initiative is the introduction of the *"Asas Sains Komputer"* (ASK) subject in selected secondary schools as part of the Form 1,2 and 3 curricula (Sidek et al., 2020).

This elective subject aims to expose students to the fundamentals of computer science and develop their problem-solving skills using computational thinking approaches. The ASK curriculum covers topics such as algorithms, programming, data representation, and computer systems. For instance, have adopted the

MIT-developed "Scratch" programming language to introduce students to basic programming concepts and foster creativity through the creation of interactive stories, games, and animations (Sidek et al., 2020).

Chongo et al. (2020) also discourse about the implementation of CT in mathematics subjects, incorporating CT concepts through the teaching of algorithmic thinking, problem decomposition, and logical reasoning. This approach encourages students to break down complex problems into smaller, manageable parts and develop step-by-step solutions using flowcharts and pseudocode. Additionally, science subjects such as physics and chemistry are also leveraging CT principles to enhance students' understanding of scientific concepts and problem-solving abilities.

Also, science subjects, such as physics and chemistry, are leveraging CT principles to enhance students' understanding of scientific concepts and problem-solving abilities. For illustration, students may use simulations and modeling tools to visualize and analyze scientific phenomena, applying computational thinking skills to interpret data and draw conclusions (Mensan et al., 2020).

The inclusion of humanities subjects in this discourse highlights the versatility of CT and its capacity to enhance the learning experience by nurturing computational thinking patterns, such as abstraction, decomposition, and algorithmic reasoning, which can be pragmatic to analyze literary texts, historical events, and philosophical arguments (Katai, 2020).

Moreover, the Malaysian government has cooperated with industry partners and NGOs to promote CT education through various ascendancies. For instance, the Malaysia Digital Economy Corporation (MDEC) launched the "Mydigitalmaker" program, which aims to foster digital creativity and innovation among students through the provision of resources, training, and competitions related to coding, robotics, and digital making. However, despite these efforts, the implementation of CT in Malaysian secondary schools is still in its early stages, and challenges remain.

More comprehensive teacher training, access to adequate technological infrastructure, and the development of a cohesive CT framework that can integrate across the curriculum are among these challenges. To further intensify CT education in Malaysia, policymakers and educators are working towards developing a more structured and comprehensive approach. This includes the creation of a national CT framework, the provision of professional development encounters for teachers, and the establishment of partnerships with industry and academia to foster a supportive ecosystem for CT education.

CONCLUSION

In today's rapidly embryonic digital landscape, computational thinking has become an indispensable skill set for students to master. Educators can empower students to become active creators, problem-solvers, and innovators in an increasingly technology-driven world by integrating computational thinking initiatives into secondary school curricula. Conversely, the journey towards successful implementation has its challenges.

Overcoming barriers such as packed curricula, lack of teacher preparation, and limited resources requires a strategic and collaborative approach. Providing teachers with comprehensive professional development opportunities is crucial, fostering their computational fluency and equipping them with the tools to teach students through immersive, project-based learning experiences.

By emphasizing real-world connections and framing computational thinking as a creative endeavor, educators can ignite students' intrinsic motivation and cultivate a deep understanding of the relevance and applicability of these skills across various domains. Malaysia has taken meaningful strides in this direction, with initiatives like introducing the "*Asas Sains Komputer*" subject and incorporating computational thinking concepts into STEM subjects.

Nonetheless, a more comprehensive and cohesive approach is necessary to truly transform the educational landscape and prepare students for the demands of the 21st century. As the nation moves forward, we must recognize that computational thinking is not merely about coding syntax or isolated technical skills.

It is about encouraging a mindset of creative problem-solving, resilience, and adaptability. By embracing student-centered pedagogies and fostering a culture of collaboration and experimentation, we can create learning environments that empower students to navigate the complexities of the digital age with confidence and ingenuity.

The journey towards integrating computational thinking into secondary education is an exciting and transformative one that demands the mutual efforts of policymakers, educators, industry partners, and the wider community to create a supportive ecosystem that nurtures the next generation of digital leaders.

By prioritizing computational literacy and investing in the necessary resources and support systems, Malaysia can position itself at the forefront of the global digital revolution, ensuring its students have the skills and mindsets needed to thrive in an increasingly interconnected and technology-driven world. By fostering a love for learning, creativity, and problem-solving, we can inspire a generation of innovators who will harness technology's power to tackle tomorrow's challenges and create a brighter, more equitable future for all.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

DECLARATION OF GENERATIVE AI

During the preparation of this work, the authors used ChatGPT to enhance the clarity of the writing. After using ChatGPT, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

DATA AVAILABILITY STATEMENT

Data available within the article or its supplementary materials.

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